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Patent Office

Ottawa, Canada
K1A 0C9

(11) (C) 1,286,032

(21) 614,358

(22) 1989/09/28

(45) 1991/07/09

(52) 354-58

C.L. CR. 88-99

88-121

350-32

(51) INTL.CL. ⁵ A61B-5/117; G06K-9/20

(19) (CA) CANADIAN PATENT (12)

(54) Optical Scanning and Recording Apparatus for
Fingerprints

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(57) 20 Claims

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ABSTRACT

In an optical fingerprinting system a truncated prism is used. The prism has an imaging surface against which a finger is applied, an illumination surface substantially parallel to the imaging surface and an inclined viewing surface between the imaging and illumination surfaces. Opposite the inclined viewing surface is another inclined surface that is coated with light absorbent material. The remaining two end surfaces of the prism may also be similarly coated. When a light source is positioned beside the illumination surface light enters the prism and causes an image of the fingerprint to be visible on the viewing surface. As a finger is rolled on the imaging surface a linear charge coupled device (CCD) may be moved in synchronism to record the whole image.

This invention relates to an improved mechanism for obtaining human fingerprints without the use of ink by means of optical scanning.

It is known to provide an optical scanning mechanism utilizing a prism against which the finger is placed. By using the principle of Total Internal Reflection it is possible to obtain a view through such a prism of the areas of contact of the ridges of the human fingerprint with the surface of the prism, due to the frustration of the mechanism of Total Internal Reflection at those points where the skin ridges make contact with the surface. When so viewed, there is a difference in contrast between the points of contact of the fingerprint and the surrounding area. See for example, United States Patent 3,482,498 (Becker), United States Patent 4,414,684 (Blonder), United States Patent 3,200,701 (White), United States Patent 3,968,476 (McMahon), United States Patent 4,210,899 (Swonger).

United States Patent 3,527,535 (Monroe) illustrates the principle of using a dark field background to enhance the contrast of such fingerprints obtained using frustrated Total Internal Reflection. Monroe utilizes a dark opaque background in order to produce a light on dark image, significantly improving the contrast ratio available in the image. However, illumination is provided through the sides of the prism only, reducing the amount of light available through scattering from the points of contact of the skin ridges with the surface of the prism.

It is a principal object of the present invention to provide a fingerprint scanning mechanism of the general type



disclosed by Monroe but which provides enhanced contrast ratio of the image and improved image capture and processing capabilities.

It is another object to provide, according to a specific embodiment of the invention consistent brightness throughout the finger contact area and additionally to provide low-cost high resolution image capturing using mechanical scanning in a tilted focal plane.

Thus, in one broad aspect of the invention, there is provided a prism means for use in a fingerprint imaging system comprising a body transparent to light having an imaging surface against which the finger to be imaged is placed, an illumination surface which is substantially parallel to the imaging surface and through which light from a source of illumination may enter the prism to strike the finger to be imaged at a substantially normal angle of incidence, a viewing surface located between the imaging surface and the illumination surface which lies at an acute angle with respect to the imaging surface, a further surface located between the imaging surface and the illumination surface and generally opposite the viewing surface such that the further surface is imaged on the viewing surface, the further surface being coated with a light absorbing coating to absorb light within the prism and prevent transmission of light into the prism from outside whereby, when a finger is placed on the imaging surface, a fingerprint image appears on the viewing surface, the fingerprint image consisting of bright fingerprint ridges on a dark background.

The preferred embodiments of our invention will be more

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particularly described hereinafter with reference to the following drawings in which:

Figure 1 is a schematic drawing of the system;

Figure 2 is a perspective view of one embodiment of the prism arrangement for use in the invention;

Figure 3 is a side elevation view of other details of

the prism arrangement;

Figure 4 is a perspective view of the relationship between the prism and CCD camera; and

Figure 5 is a schematic view illustrating a refinement of the system.

Referring to Figure 1, a truncated prism 1 is provided, against the top surface of which the fingerprint to be imaged is applied. Prism holders 2, 3 maintain the truncated prism in place. Load cells 4, 5 attached to prism holders 2 and 3 are sensitive to the downward force placed upon them and output signals 6 and 7 respectively which are proportional to the magnitude of the force upon the respective load cells. By utilizing a balance beam effect, it is possible for the control electronics module 8 to determine the lateral position of the finger as shown in Figure 1 at any given time relative to the load cells. This information is then used to control the positioning of a portion of a so-called camera 9 as will be explained in detail hereinafter.

Figure 2 and Figure 3 illustrate the general arrangement of the prism 1. The prism is made of any suitable material transparent to light and having a refractive index greater than that of air. Both glass and plastics are suitable types of materials for the manufacture of the prism.

The prism of the preferred embodiment is manufactured in the shape of a truncated prism, that is to say with its apex

removed and a flat surface disposed in its place parallel to the opposite side of the prism. A light source 12 is shone through the truncated apex directly onto the opposite surface 11 of the prism at a substantially normal angle of incidence. This surface 11 forms an interface between the material of the prism and the surrounding air such that light striking the interface at angles greater than the critical angle, measured normally to the interface, is totally reflected internally. Light striking the interface at angles below the critical angle, measured normally to the interface, is refracted and passes through. The critical angle for glass or plastics is typically of the order of 42° . Therefore, light striking the interface from the light source 12 disposed below the truncated apex of the prism will generally strike the interface 11 and pass through into the surrounding air.

On the rear face 13 of the prism and on parallel end surfaces 19, a light absorbing coating 14 is applied in order to prevent light from passing through the surface from outside or being reflected internally. Consequently, little or no light will emanate from surface 13 in such a fashion that it will be reflected internally by surface 11 and visible through surface 15. Consequently, the view through surface 15 into the prism will be dark as all illumination from lamp 12 will pass through the prism surface 11 and out into the air above the prism. It is noted that, although light absorbing coatings are preferred on the parallel end surfaces 19 and 20 to reduce reflections, these are not absolutely necessary.

When a finger is applied to the top or imaging surface

11, the ridges of the fingerprint which makes direct contact with the prism will cause light to be dispersed back into the prism and some of this light will pass through viewing surface 15 whereas the valleys of the fingerprint which do not come into contact with the prism will continue to appear dark when viewed through the prism at or above the critical angle. Accordingly, when viewed through surface 15 above the critical angle, a sharply delineated fingerprint image will be visible against a dark background.

Stripes 16 of opaque material may be provided along the illumination surface 17 of the prism such that there is more
10 opaque material in the middle than at the ends (i.e. where surface 17 joins surfaces 13 and 15). This has the effect of equalizing the light intensity from source 12 to provide even illumination of the contact area of the finger with surface 11 and to substantially correct for illumination drop-off along the contact surface due to perspective. The provision of the stripes of opaque material ensures that illumination is substantially even along both axes of the area of contact of the finger with imaging surface 11. The same equalization effect could be achieved by
20 other means, for example, by coating the lamp 12 itself in a gradated thickness or density fashion to again reduce the illumination near the centre.

In addition, a light shield 18 is provided to prevent light from source 12 reaching the observer directly. In consequence, essentially all of the light reaching an observer viewing through viewing surface 15 above the critical angle will come from only the light scattered by the ridges of the

fingerprint against contact surface 11, thus providing a fingerprint image with greatly enhanced contrast.

The prism may be in the form of a truncated triangle in profile as shown or any other shape having two sides which meet at an acute angle. In such a case, it is most preferable that one of the faces defining the acute angle meet two other faces which are parallel to each other, one of these serving as an imaging surface and the other as an illumination surface. However, even if the illumination surface is not parallel to the imaging surface, the principle of the invention could still be achieved but with less efficiency. Even if the apex were left intact and the light directed through the apex itself, the principle of the invention could be demonstrated although the very uneven illumination of the imaging surface would cause uneven brightness of the image.

Figure 1 and Figure 4 show the means by which image data is captured. As the finger is rolled on the prism in order to produce a rolled fingerprint as is customary, load cells 4 and 5 sense the relative position of the finger on the prism and produce output signals 6 and 7 which are fed to the control electronics module 8. This module is then used to move linearly a linearly arranged CCD (charge coupled device) sensor 20 incorporated in camera 9 and shown in Figure 4. Light from the contact surface 11 is focused by an optical lens 21 onto the CCD sensor 20. As the CCD sensor is essentially linear, the fingerprint information focused on the CCD sensor will represent a linear sampling across one direction of the fingerprint image on viewing surface 15. The CCD sensor is only capable of reading a line of information at a

time, thus necessitating the CCD 20 to be scanned across the width of the fingerprint image 25 shown in Figure 4. The control electronics module 8 in Figure 1 provides a signal on a drive line 26 to move CCD 20 in accordance with the positioning of the finger on the prism 1 at any given time in order to produce an optimized set of data readings to the CCD sensor representing a full rolled fingerprint image. As shown in Figure 1, a feedback line 27 from camera 9 to module 8 for positioning of the CCD 20 is provided as well as an analog line 28 which feeds analog signals from the CCD 20 to the module 8. Module 8 processes these analog signals to provide a digitizing fingerprint data output on line 29.

For example, it is possible to perform manipulations to the data to invert the contrast such that light areas are displayed as dark and dark areas displayed as light. In this case, the ridges would then be dark and the valleys and background light, rendering an image equivalent to an ink impression, though retaining the contrast advantage obtained by means of the dark field illumination used to obtain the image in the first place.

Similarly, computer processing will allow scaling of the image to any desired size and the juxtapositioning of multiple images in order to obtain composite images. An example of such a composite image would be all of the fingers on a hand for instance. These as well could then be scaled, inverted if desired and otherwise manipulated to be printed and displayed in a optimum fashion.

Although not shown in the drawings, it is also possible to obtain an image of contact of a fingerprint over more than a

simple plane. The use of a partially compliant prism surface 11 would permit more of the fingerprint pattern to be visible at any given time. This would allow side features of the finger to be obtained without rolling and would also allow patterns from rounded parts of the body such as the palm to be imaged in a better fashion.

Such a compliant prism would be fluid filled with the contact surface made of thin plastic. A constantly descending index of refraction from the contact surface through the prism would need to be maintained with the contact surface being somewhat stiffer than the skin of the human finger so that air gaps were maintained between the prism surface and the valleys.

It should be noted that because the finger is rolled along imaging surface 11 and viewed through viewing surface 15 which is inclined at an angle to surface 11 some defocussing caused by differences in depth of view occurs. This can be compensated for, as shown in Figure 5, by tilting the linear CCD 20 out of normal with regard to the optical axis 30 through lens 21. The tilt angle will depend on different parameters such as the refractive index of the prism material and the prism angles but typically a tilt angle of between 30° and 35° has proven advantageous.

As described above, the CCD 20 alone, rather than the whole camera is moved as the finger is rolled. In general the inertia of the camera and lens assembly would be too great to use movement of the assembly for scanning during rolling of a finger. However, where a plain impression of four stationary fingers is to

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be obtained the inertia of the camera is not problematic and so the whole camera can be moved to capture the images of all four prints.

Although a CCD is particularly described, any suitable photosensitive detector means such as a charge injection device (CID) or photodiode array could be used.

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THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE
PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A prism means for use in a fingerprint imaging system comprising a body transparent to light having
an imaging surface against which the finger to be imaged is placed,
an illumination surface which is substantially parallel to the imaging surface and through which light from a source of illumination may enter the prism to strike the finger to be imaged at a substantially normal angle of incidence,
a viewing surface located between the imaging surface and the illumination surface which lies at an acute angle with respect to the imaging surface,
a further surface located between the imaging surface and the illumination surface and generally opposite the viewing surface such that the further surface is imaged on the viewing surface, the further surface being coated with a light absorbing coating to absorb light within the prism and prevent transmission of light into the prism from outside whereby, when a finger is placed on the imaging surface, a fingerprint image appears on the viewing surface, the fingerprint image consisting of bright fingerprint ridges on a dark background.
2. The prism as defined in claim 1 wherein the shape of the prism in profile is that of a truncated triangle having a base serving as the imaging surface, a truncated surface serving as the

illumination surface, a first inclined surface serving as the viewing surface, a second inclined surface which is the coated further surface and two parallel end surfaces.

3. The prism as defined in claim 1 wherein means are provided to equalize substantially illumination across the imaging surface.
4. The prism as defined in claim 3 wherein the equalization means is opaque stripes provided on the illumination surface.
5. The prism as defined in claims 1, 2, 3 or 4 wherein a light shield means is provided to prevent light from the source of illumination being transmitted directly to imaging means used to capture the fingerprint image transmitted through the viewing surface.
6. A prism as defined in claim 1, 2, 3 or 4 in which all surfaces of the prism except the imaging, illumination and viewing surfaces are coated with light absorbing material.
7. An apparatus for use in a fingerprint imaging system comprising:
 - a) a source of illumination,
 - b) a prism comprising a body transparent to lighthaving,
 - an imaging surface against which the finger to be imaged

is placed,

an apex opposite the imaging surface and located proximate the source of illumination such that light from the source of illumination may enter the prism through the apex to strike the finger to be imaged,

a viewing surface located between the imaging surface and the illumination surface which lies at an acute angle with respect to the imaging surface,

a further surface located between the imaging surface and the illumination surface and generally opposite the viewing surface such that the further surface is imaged on the viewing surface, the further surface being coated with a light absorbing coating to absorb light within the prism and prevent transmission of light into the prism from outside whereby, when a finger is placed on the imaging surface, a fingerprint image appears on the viewing surface, the fingerprint image consisting of bright fingerprint ridges on a dark background;

c) imaging means for capture the fingerprint image transmitted through the viewing surface; and

d) a light shield means to prevent light from the source of illumination being transmitted directly to the imaging means.

8. An apparatus for use in a fingerprint imaging system comprising:

a) a source of illumination;

b) a prism comprising a body transparent to light

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having:

an imaging surface against which the finger to be imaged is placed

an illumination surface which is opposite to the imaging surface and located proximate the source of illumination such that light from a source of illumination may enter the prism through the illumination surface to strike the finger to be imaged,

a viewing surface located between the imaging surface and the illumination surface which lies at an acute angle with respect to the imaging surface,

a further surface located between the imaging surface and the illumination surface and generally opposite the viewing surface such that the further surface is imaged on the viewing surface, the further surface being coated with a light absorbing coating to absorb light within the prism and prevent transmission of light into the prism from outside whereby, when a finger is placed on the imaging surface, a fingerprint image appears on the viewing surface, the fingerprint image consisting of bright fingerprint ridges on a dark background;

c) imaging means for capture the fingerprint image transmitted through the viewing surface; and

d) a light shield means to prevent light from the source of illumination being transmitted directly to the imaging means.

9. An apparatus for use in a fingerprint imaging system comprising:

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- a) a source of illumination;
- b) a prism comprising a body transparent to light

having:

an imaging surface against which the finger to be imaged is placed,

an illumination surface which is substantially parallel to the imaging surface and located proximate the source of illumination such that light from a source of illumination may enter the prism through the illumination surface to strike the finger to be imaged at a substantially normal angle of incidence,

a viewing surface located between the imaging surface and the illumination surface which lies at an acute angle with respect to the imaging surface,

a further surface located between the imaging surface and the illumination surface and generally opposite the viewing surface such that the further surface is imaged on the viewing surface, the further surface being coated with a light absorbing coating to absorb light within the prism and prevent transmission of light into the prism from outside whereby, when a finger is placed on the imaging surface, a fingerprint image appears on the viewing surface, the fingerprint image consisting of bright fingerprint ridges on a dark background;

c) imaging means for capture the fingerprint image transmitted through the viewing surface; and

d) a light shield means to prevent light from the source of illumination being transmitted directly to the imaging means.

10. The apparatus as defined in claim 9 wherein the shape of the prism in profile is that of a truncated triangle having a base serving as the imaging surface, a truncated surface serving as the illumination surface, a first inclined surface serving as the viewing surface, a second inclined surface which is the coated further surface and two parallel end surfaces.
11. The prism as defined in claim 10 wherein means are provided to equalize substantially illumination across the imaging surface.
12. The apparatus as defined in claim 11 wherein the equalization means is opaque strips provides on the illumination surface.
13. The apparatus defined in claim 7, 8 or 9 in which all surfaces of the prism except the imaging, illumination and viewing surfaces are coated within light absorbent material.
14. The apparatus defined in claim 10, 11 or 12 in which all surfaces of the prism except the imaging, illumination and viewing surfaces are coated with light absorbent material.
15. A fingerprint imaging systems comprising:
prism means;
illumination means;
load cell means at supports for the prism;

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camera means including a linearly arranged
photosensitive detector means; and

servo means for positioning the photosensitive detector
means in response to signals from the load cell means as a finger
is rolled on the prism; and

image processing and storage means; wherein the prism
means comprises a body transparent to light having

an imaging surface against which the finger to be imaged
is placed;

an illumination surface which is substantially parallel
to the imaging surface and through which light from a source of
illumination may enter the prism to strike the finger to be imaged
at a substantially normal angle of incidence,

a viewing surface located between the imaging surface
and the illumination surface which lies at an acute angle with
respect to the imaging surface and through which the fingerprint
image is transmitted to the photosensitive detection means,

a further surface located between the imaging surface
and the illumination surface and generally opposite the viewing
surface such that the further surface is imaged on the viewing
surface, the further surface being coated with a light absorbing
coating to absorb light within the prism and prevent transmission
of light into the prism from outside whereby, when a finger is
placed on the imaging surface, a fingerprint image appears on the
viewing surface, the fingerprint image consisting of bright
fingerprint ridges on a dark background.

16. The system defined in claim 15 wherein the shape of the prism in profile is that of a truncated triangle having a base serving as the imaging surface, a truncated surface serving as the illumination surface, a first inclined surface serving as the viewing surface, a second inclined surface which is the coated further surface and two parallel end surfaces.

17. The system defined in claim 16 wherein means are provided to equalize substantially illumination across the imaging surface.

18. The system defined in claim 17 wherein the equalization means is opaque stripes provided on the illumination surface.

19. The system defined in claim 15 wherein the photosensitive detector means is a CCD.

20. The system defined in claim 15, 16, 17, 18 or 19 wherein the photosensitive detector means is tilted at an angle with respect to the light path from the imaging surface to compensate for depth of view differences.

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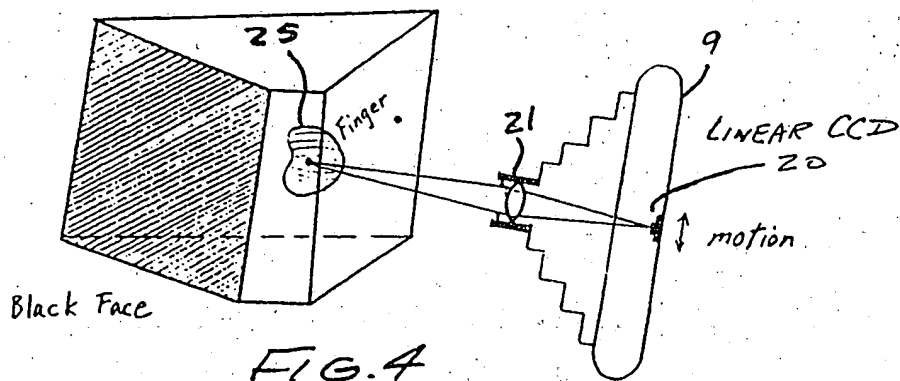
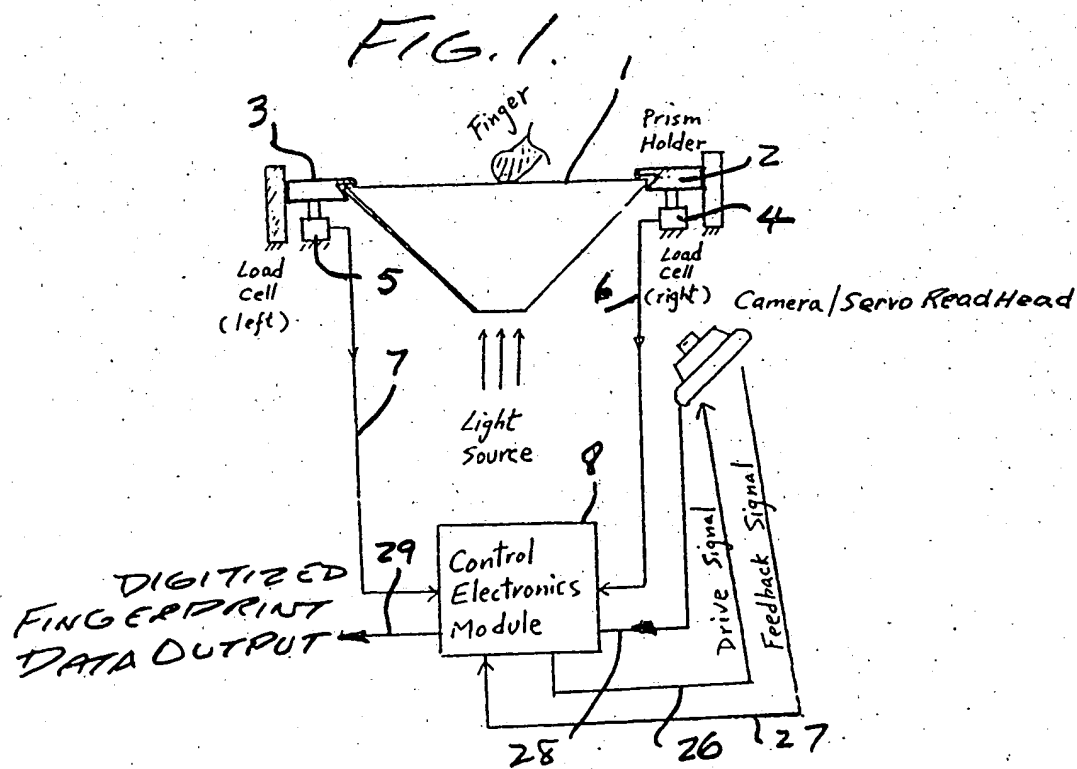
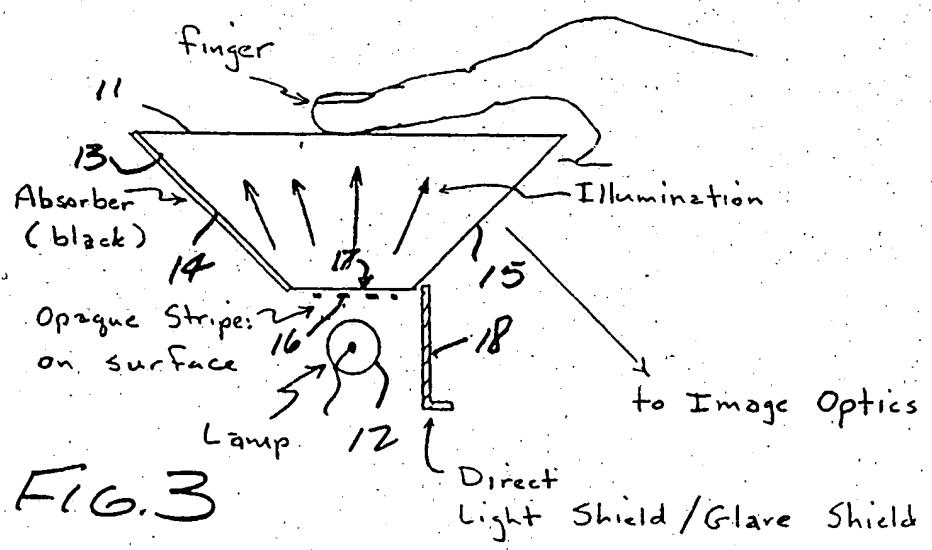
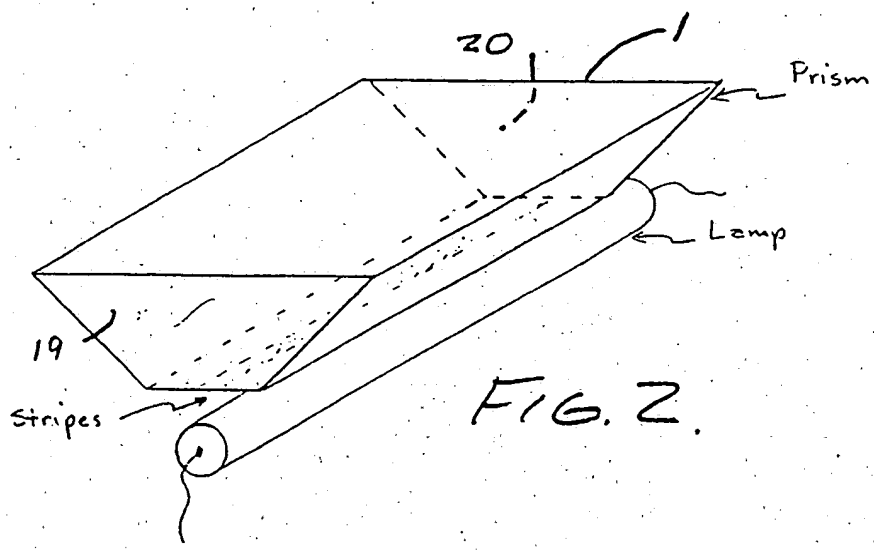


FIG. 4.



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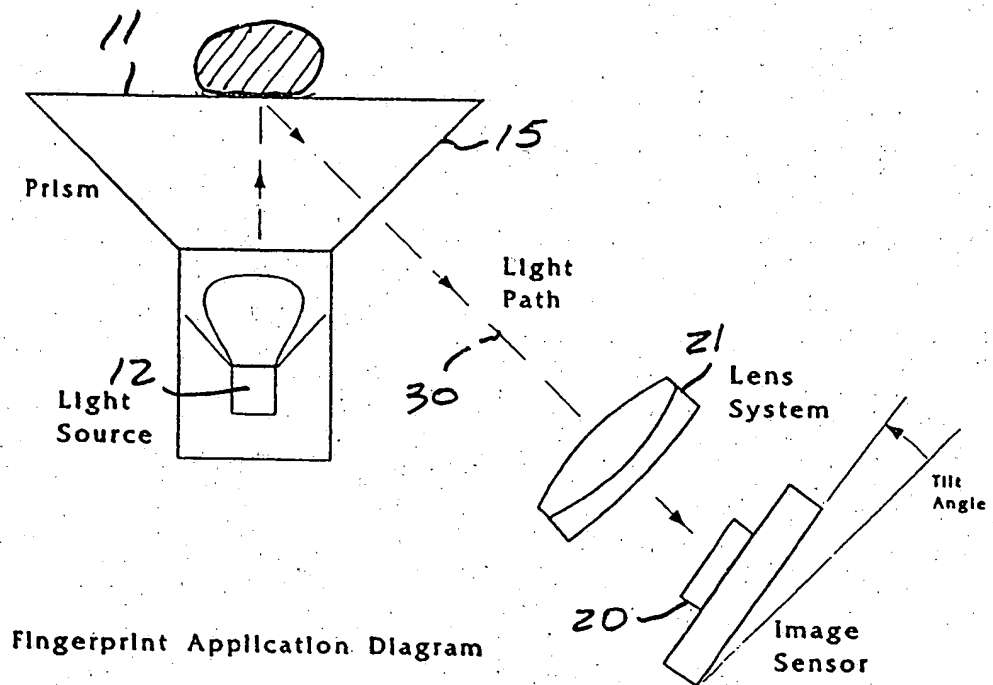


FIG. 5